

DER communication over a WAN Using SEP 2.0 versus IEC 62541 OPC UA

This white paper compares the two communication technologies: Smart Energy Profile (SEP) 2.0 and IEC 62541 OPC Unified Architecture (UA) as well as provides an introduction to OPC UA. SEP 2.0, was developed for LAN communication and employs a REST protocol style. OPC UA was developed for LAN or WAN communication and employs a “Stateful Communication” protocol style. Stateless REST servers don’t store communication/protocol information for clients for the duration of a conversation¹ while stateful servers do. Both approaches can work and both have advantages and disadvantages. Whether stateless or stateful servers should be used depends on the use case.

The REST approach is very simple to understand and can be executed on almost any client or server that has HTTP/HTTPS support. REST provides ease of development and greater reuse of the existing World Wide Web infrastructure. REST works really well for the World Wide Web because REST provides:

- Totally stateless operations: Create, Read, Update, and Delete (CRUD).
- A very scalable solution when you have few servers and a large number of clients.

If a large number of clients don’t need to simultaneously connect to servers, a stateful server can greatly optimize communication by supporting communication context information and conversation state management. Figure 1 illustrates these two different architectures:

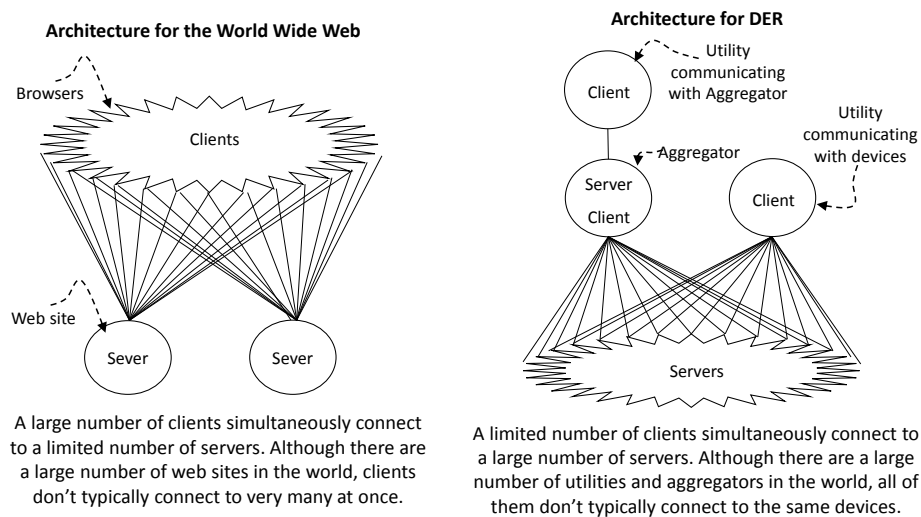


Figure 1: The World Wide Web and DER device communication use cases

¹ This document uses the term conversation to mean a set of related client-server interactions. The technical term for a conversation is “session”.

Figure 1 illustrates a web site supporting thousands of simultaneous browser connections. DER communication does not have this requirement and in fact includes the opposite requirement of thousands of simultaneous server connections.

Maintaining conversation state in the server provides crucial benefits when a client needs to talk to a large number of servers:

- **Enhanced Security:** REST does not support conversations/sessions that span CRUD operations so credentials must be passed every time a client connects. Passing in user credentials such as a certificate at every connection is very processing intensive on the server side and consumes network bandwidth. To avoid this issue, REST servers typically store cookies on the client machine as identifiers for user sessions to avoid having to repeatedly pass credentials. However, if a server uses cookies on the client as session identifiers, attackers can impersonate users' requests by stealing a victims' cookies. When using a stateful protocol, the server can safely store security credentials for a client application for the length of a long lived communication session².
- **End to end security versus point to point security:** REST typically relies on a secure connection from one machine to another (point to point security). OPC UA secures each individual message sent by an application within a machine (end to end security). Application to application security provides far greater protection than machine to machine security especially in the case where an intruder has access to a DER device.
- **OPC UA includes a standard way to manage LAN and WAN device discovery** via a local registry or via a global registry which includes optional certificate management³.

Figure 1 also shows a utility connecting to an aggregator exposing information about thousands of devices. Maintaining conversation state in the server also provides benefits when a client needs to talk to complex servers that aggregate a large number of devices. Because the SEP 2.0 use case focuses on communication with a limited number of devices, SEP 2.0 servers do not readily scale up to support exposing information about thousands of devices. This is clearly demonstrated via SEP 2.0 mechanism for exposing data about multiple items using "Lists". A SEP 2.0 List is an array of items with the same schema. But, SEP 2.0 does not provide a way of searching or sub setting items in a List. OPC UA provides the following benefits when compared to REST.

² While the session issue can be mitigated by communicating over a VPN, a VPN is another system that needs to be independently configured/secured/managed and does not support end to end security.

³ <https://www.youtube.com/watch?v=TCy8JlnWIXw>

- Enhanced ability to provide data filtering for large servers (aggregated devices): Unlike SEP 2.0 Lists, an OPC UA servers can maintain subgroups of items that the client is interested in. For example, if a client is only interested in measurements related to a particular geographic region, the server can persist a list of items and only send data changes related to the listed items. This capability is particularly important when a server exposes information about a large number of devices. In this case, without filtering, clients are often required to process a large amount of unwanted data. When using OPC UA, a client configured subgroup of items is called a “View”.

OPC UA Views are used to present data to clients when they read, write, query, or subscribe to data. The view illustrated below could enable a user to write information only about a group or subgroup of devices.

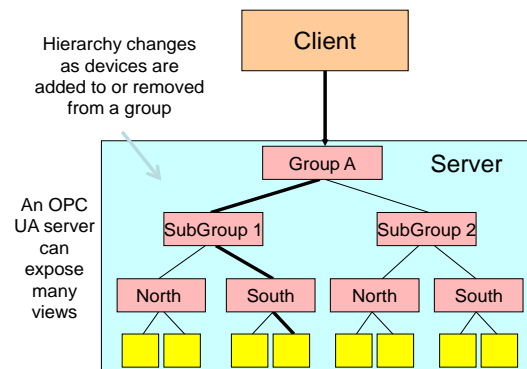


Figure 2: OPC UA Grouping

- More efficient exchange of reoccurring information in a “packed” format using small IDs local to the client to identify data instead of larger globally unique IDs (MRIDs). This optimization results in significantly smaller messages and ease of processing by the client.
- A guaranteed level of reliability: OPC UA clients and servers can perform timely detection and rapid recovery from WAN communication failure by using a keep-alive. The keep-alive interval can be negotiated by OPC UA client and server when communication is initialized. The keep-alive allows:
 - Both client and server to monitor communication activity and recover more quickly after a failure has been detected.
 - Resynchronization after communication failure with an existing session with no loss of data. OPC UA servers cache a configurable number of notifications until being acknowledged allowing retransmission in the event of WAN communication failure.

- Enhanced ability to perform queries: Query results often include too much data to return in a single response message. OPC UA allows a server to maintain a “continuation point” so that the server can send a large result in multiple messages.
- Operations that span multiple client or server actions: Many activities within a utility require that a client make multiple calls into a server or multiple server notifications to a client. Those calls and notifications must be treated as a group. For example, executing a long running calculation or alarm management are best handled by OPC UA and not REST.
- Control: Device control typically involves a sequence of service calls. To manage the lifecycle of these "transactions" some sort of session that spans an entire conversation must be established.
- Intermittently connected clients: An intermittently connected client requires that data be cached on the server for retrieval when the client is on line. This is not practical using REST since the server does not know what data the client may have already received.
- Subscription: While REST frequently employs a polling based architecture, SEP 2.0 includes subscriptions. SEP 2.0 publishers are REST clients. That is, a SEP 2.0 device that supports subscriptions must act not only as a REST server, but also a REST client. However, implementing both client and server function in a component fundamentally undermines the simplicity that a REST based architecture provides. For example, a publisher must be able to handle connection time-outs. This logic is best implemented using a toolkit, but SEP 2.0 toolkits which implement reliable publication are not widely available.
- Availability –OPC UA application level redundancy features and functionality include defining how redundant clients and servers interoperate with regard to application failover. This allows systems that are composed of clients and servers from different vendors to still supply high availability. Since SEP 2.0 components that support subscriptions must act as both a client and a server, the vast array of products that support highly available REST based web servers are not readily reused.
- Scalability – OPC UA has been widely implemented in small embedded controllers and as an interface to a large system. To support the embedded devices, OPC UA’s messaging scheme has been designed so that client and server can negotiate communication parameters. In this way, a client can discover at run-time the capabilities of a resource constrained device. At the high end, OPC UA includes the capability to implement load balancing and server federation to enable simultaneous communication with a vast number of devices. The key is that clients can easily discover the functionality supported by a server.

Overview of OPC UA

The diagram below illustrates the conceptual partitioning of the OPC UA specifications.

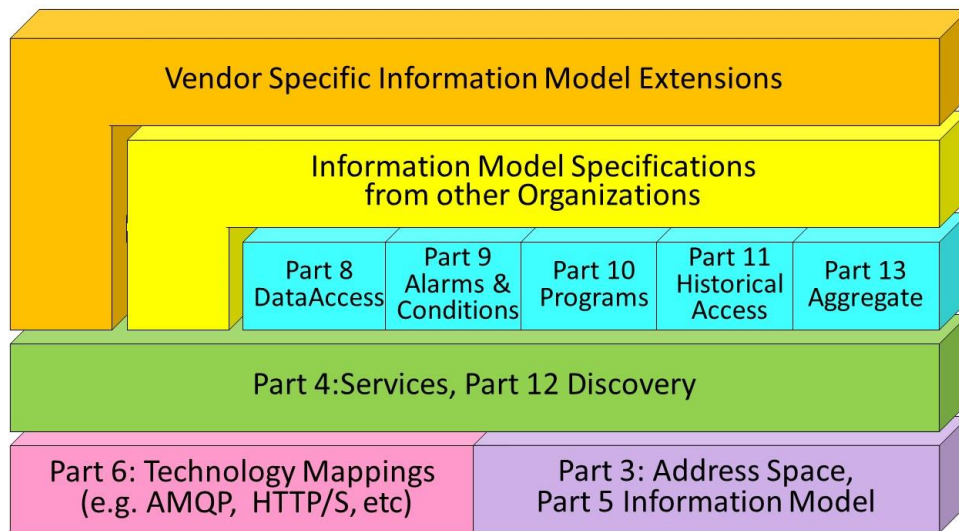


Figure 3: The OPC UA Layers Separate the Protocol from the Data Model

As shown above, OPC UA does not prescribe a domain model, but can be used to convey a large variety of hierarchical models such as SEP 2.0, SunSpec data model, IEC 61850, or complex models such as IEC CIM, or ASHRAE 201P. OPC UA provides a larger set of services besides CRUD operations to facilitate richer conversations. OPC UA services can make use of a variety of underlying protocols such as over HTTP/HTTPS, directly over TCP, or over AMQP. It makes use of XML or binary encoding and of appropriate security technology to ensure that the data on the wire is secure. This functionality is provided by the OPC UA Protocol Stacks which are provided by the OPC Foundation to ensure interoperability. A number of vendors provide SDK's, toolkits or other API from which application can be developed.

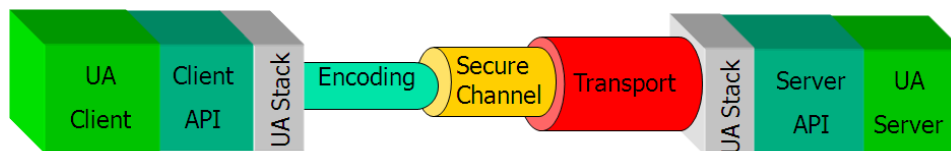


Figure 4: OPC UA Protocol Modularity

OPC UA includes multiple levels of security. It provides secure data on the wire by providing encryption and signing. OPC UA provides fine grain access control to individual instance and properties on a per user role basis. It provides auditing capabilities to ensure traceability.

Migration to OPC UA

Most widely used SCADA systems and device gateways sold today support an older version of OPC called OPC DA. The use of OPC DA by ABB is typical as shown below:

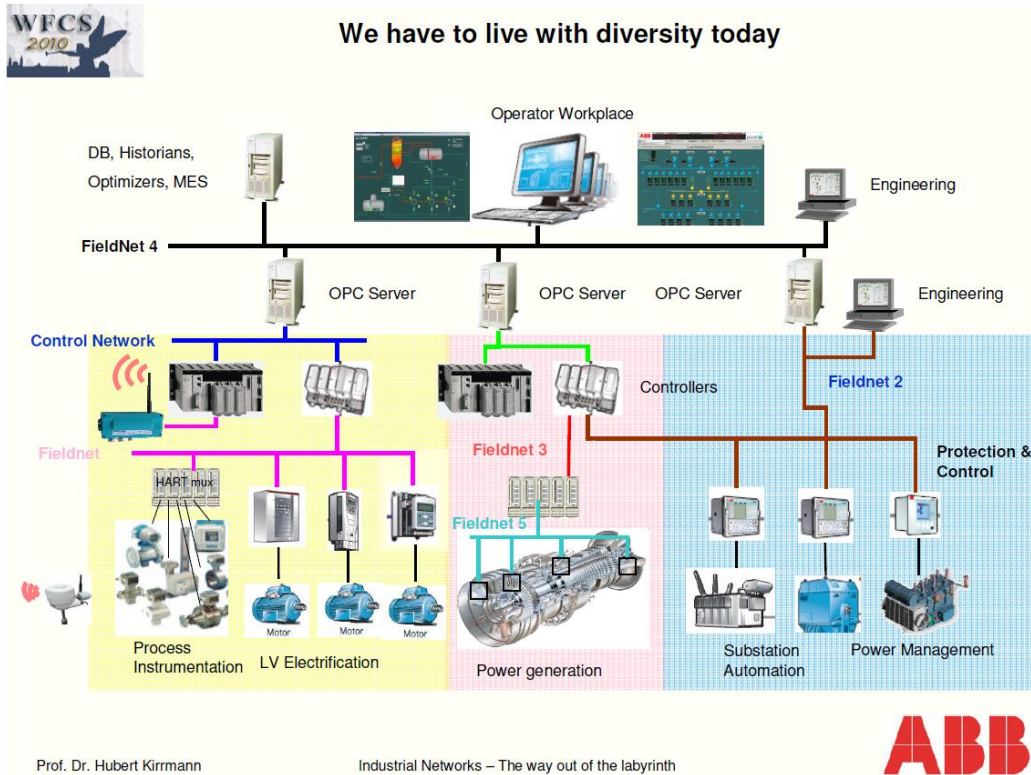


Figure 5: OPC DA Based Integration of Heterogeneous Networks

The diagram below illustrates how an OPC DA interface on an existing SCADA system can be extended to run over a WAN using OPC UA. It should be noted that this can be done with off-the-shelf components supplied by the OPC Foundation and other suppliers.

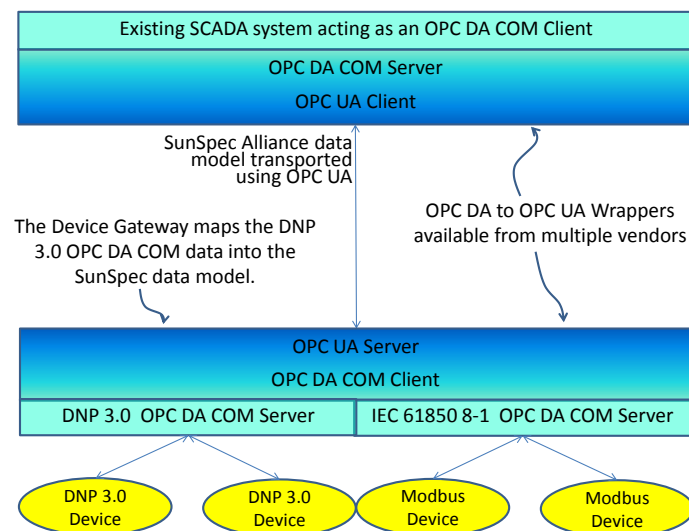
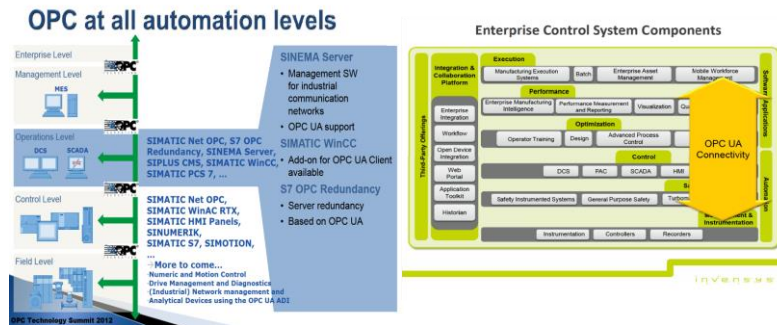


Figure 6: Migrating Existing SCADA Systems and Devices

Interoperability with End User and Power Generation Control Systems

Industrial Demand Side Resource (DSR) control systems typically consist of industrial control systems. For example, Invensys, which has recently become part of Schneider, is adding support for OPC UA from controllers to Enterprise Resource Planning (ERP) systems. In fact, Siemens, GE, and Schneider are all following a similar strategy



GE has announced that it has “*OPC-UA Deployed across Connected Controls Platform*” and “*plans for consolidation of the company’s control platforms to enable the Industrial Internet.*” GE is creating a “*Single platform, comprehensive automation, embedded models will allow customers to get the most out of high performance assets with world-class systems integration.*” GE will “*Focus on global industry standards, security and high performance in today’s connected world with standardization on OPC-UA, PROFINET across the platform*” .
<http://www.ge-ip.com/news/ge-invests-in-the-future-with-controls-convergence-strategy/n3147>

Figure 7: SCADA for Power Generation and OPC UA

SAP’s MII and IBM Manufacturing Integration Bus products provides an example of ERP to control system integration using OPC UA.:

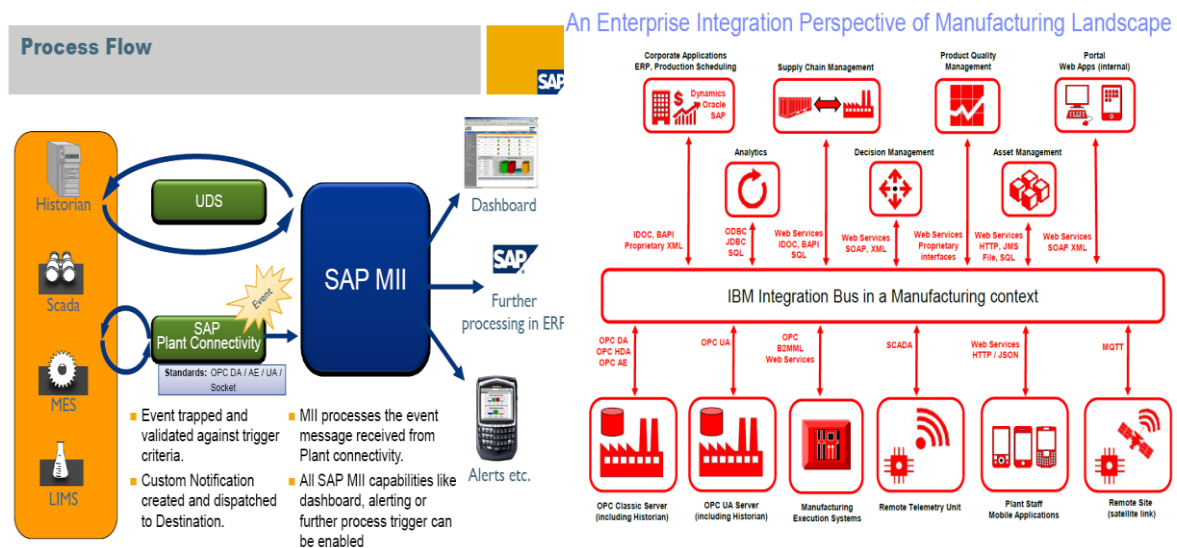
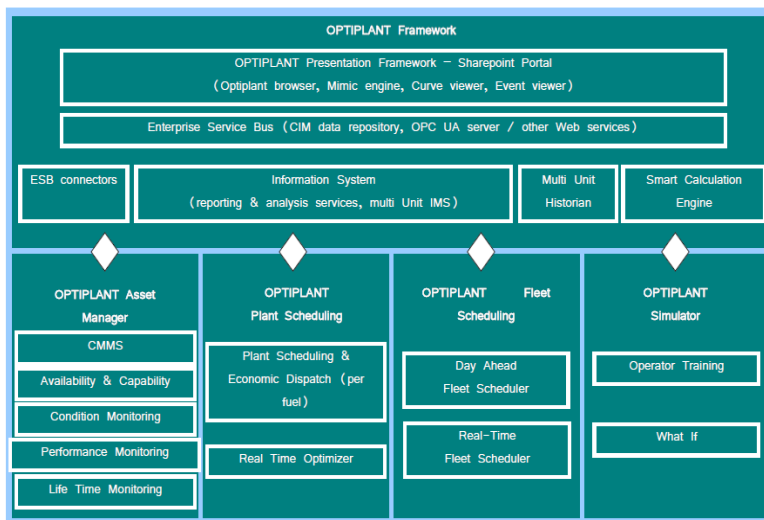


Figure 8: SAP and IBM Support OPC UA

Industrial automation technology such as from Rockwell Automation or Honeywell is also typically used to control hydro and fossil power plants and now support OPC UA. Alstom's Optiplant framework supports OPC UA:

Optiplant implementation : Applications software



ALSTOM Power Automation and Control - Extending the CIM for Generation - 2012-05-18 - P 13

Figure 9: Alstom Optiplant uses OPC UA to Expose CIM Data

Yokogawa VigilantPlant support OPC UA:

The image displays the Yokogawa VigilantPlant product catalog and project examples. The top section, titled "Engineering / Services", lists various products and services:

- Production Management**: Quantum, ExploNet, CAMS for HIS, PRM, EESMOC, Real-time Production Organizer.
- Control Systems**: UNIVIEW UA Server, P-Base-OS, YOKOGAWA, FA-MANV, UA Client.
- Field Instruments (Sensors, Transmitters)**: Expertise Recorder (DX1000/DX2000), Data Acquisition and Monitoring MX1000, Variable Area Flowmeter, Coriolis Flowmeter, Vortex DVT, Magnetic AQS, Ultrasonic US900, YTA50/70, YTA500/200, DTEX 200, 2SA1.00 wireless.

The bottom section, titled "Yokogawa Solar Experience", shows project examples:

- SEGS 1 and 2 Steam Plant Controls, Instruments, Data Acquisition, Tracking Controls, Wireless.
- Leading Collector OEM (NDA) – Tracking Controls, Field Instruments, Data Acquisition, Networking.
- ANU Big Dish Tracking Controls and SCADA.
- Daido Steel CPV Tracking Controls.
- Three Start-up Companies (NDA) PV Tracking.
- Australian Industrial Heating (NDA) Tracking Controls.
- Two Start-ups (NDA) – CSTP Tracking.

VigilantPlant can act as an IEC 62541 Client or Server

VigilantPlant Deployed for Concentrated Solar Thermal Power Control System

Figure 10: Yokogawa Supports OPC UA

Mitsubishi Electric's IQ Plant Suite is used in many fossil power plants:

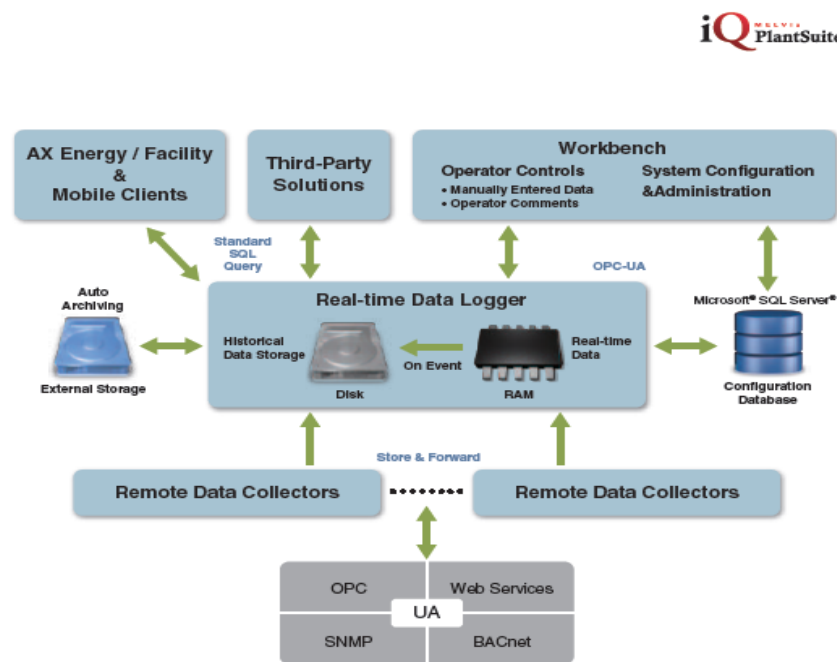


Figure 11: Mitsubishi Electric Supports OPC UA

OPC UA is used by Schneider to interface to power system network applications.



Figure 12: Operations Technology/Schneider and OPC UA

Prediktor is used to control and optimize PV installed by Scantec Solar. Prediktor specializes in real-time, model based solutions for decision support or closed loop control. Prediktor's solution support OPC UA.

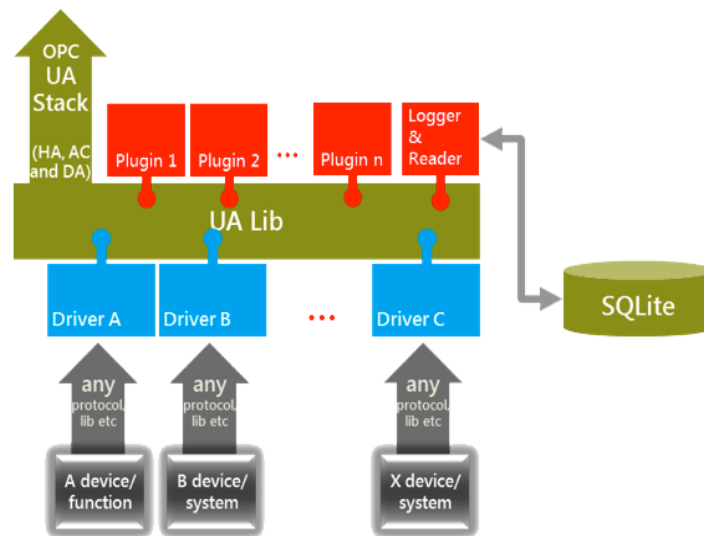


Figure 13: Prediktor/Scantec Solar and OPC UA

Bachmann's Atvise product is embedded in Danfoss power generation SCADA.

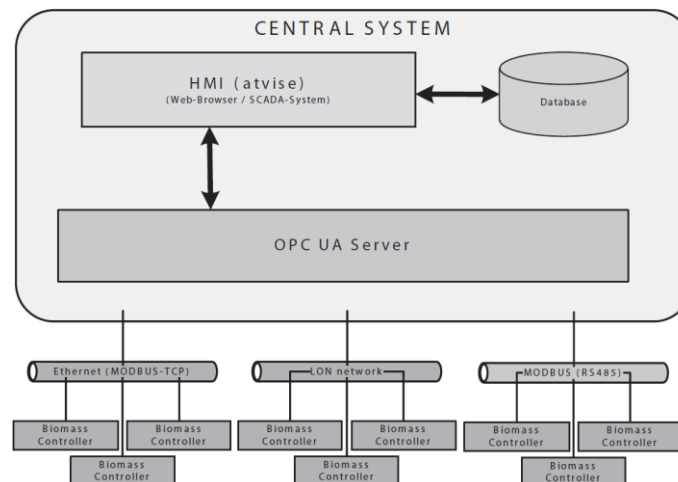


Figure 14: Danfoss SCADA for Power Generation

BAX Energy Energy Studio Pro generation management software can employ OPC UA to provide wind turbine and solar power equipment data to enterprise systems.

The screenshot displays the BAX Energy Studio Pro website. At the top, there's a navigation bar with 'HOME', 'ENERGY STUDIO PRO', and 'COMPANY'. Below this, a large banner features a wind turbine and a central graphic with four stacked, colorful circles labeled 'OPTIMIZE', 'ORGANIZE', 'ANALYZE', and 'VISUALIZE'. To the right of this graphic, text describes the software's capabilities: connecting to energy assets for visualization and analysis, and managing a mixed portfolio of solar, wind, hydro, and bio power plants. A 'Latest news' section mentions that BAX Energy became a Corporate Member of the OPC Foundation in October 2012. Below the banner, the website lists supported standards and connects to various wind turbines, solar inverters, and string monitors.

Energy Studio Pro® supports the following standards:

- IEC 60870-5-104 (Substations)
- IEC 61400-25 (Wtg connection)
- OPC DA (Data access)
- OPC UA (Unified architecture)
- OLEDB
- SAP
- VDI 3423
- IEC 60870-5-101 (Substations)
- IEC 61400-12 (Power performance)
- OPC Xi (Express interface)
- Web Services
- OSISOFT PI
- RDS-PP

Connect to multiple wind turbines:

- Enercon
- Vestas
- Siemens
- REpower
- Gamesa
- DeWind
- NEG Micon
- Nordex
- Fuhrlander
- GE
- Mitsubishi
- Suzlon
- AREVA
- Acciona and more...

Connect to multiple solar inverters:

- ABB
- Siemens
- SunPower
- AnswerDrivers
- Bonfiglioli
- Delta Energy System
- Fimer Siel Siac
- SolarMax
- PowerOne
- SMA
- AEG
- Aros
- Carlo Gavazzi
- Elettronica Santerno
- Friem
- Sungrow
- Fronius
- Gamesa
- Gefran
- Helios System
- Ingecon/Ingeteam
- Jema
- Kaco
- SunSys
- Kostal Pico
- Mastervolt
- Motech
- Omron
- Riello
- Schneider
- Socomec
- Satcon

Support for multiple string monitors:

- Power-One
- Italweber
- Ingecon
- Bonfiglioli
- Elettronica Santerno
- Weidmuller
- Aros
- Carlo Gavazzi
- Satcon
- Phoenix Contact
- and more...

Figure 15: BAX Energy Studio Uses OPC UA to Integrate Solar Power information

SMA supports OPC and can employ the OPC DA to OPC UA wrapper to expose an aggregator interface.

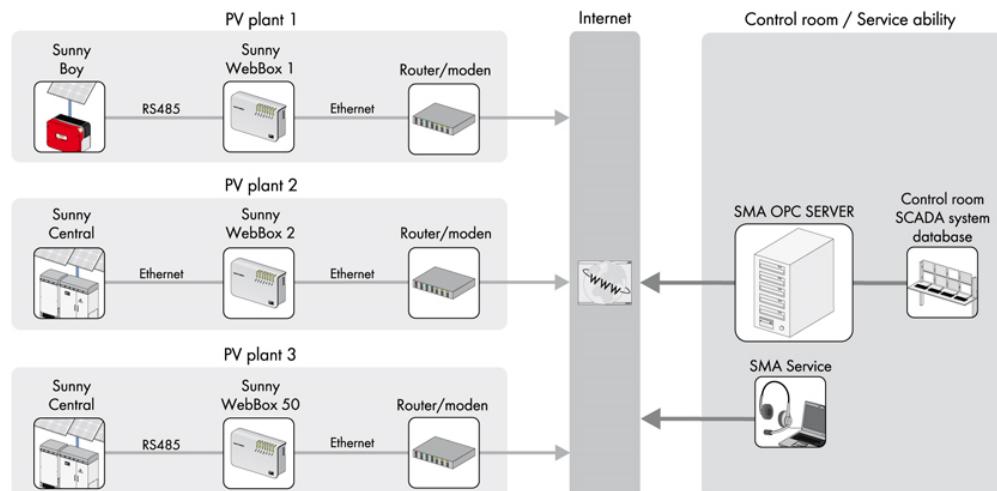


Figure 16: SMA Uses OPC DA to Integrate Solar Power information

Interoperability with Building Automation/Facilities Management Systems

Many DER devices are managed by end user energy management systems such as Building Automation or Facilities Management Systems (BA/FMS). OPC UA is already widely used in the BA/FMS industry. Building automation systems are often integrated using a generic OPC UA based HMI product such as Iconics Genesis.

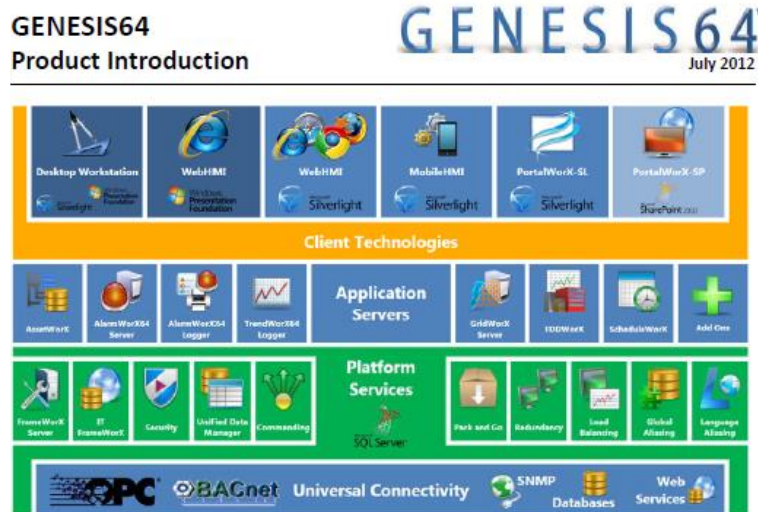


Figure 17: Iconics Building Automation Supports OPC UA

Alternatively, Building automation systems are often integrated using a building automation specific HMI product such as NETXAutomation.

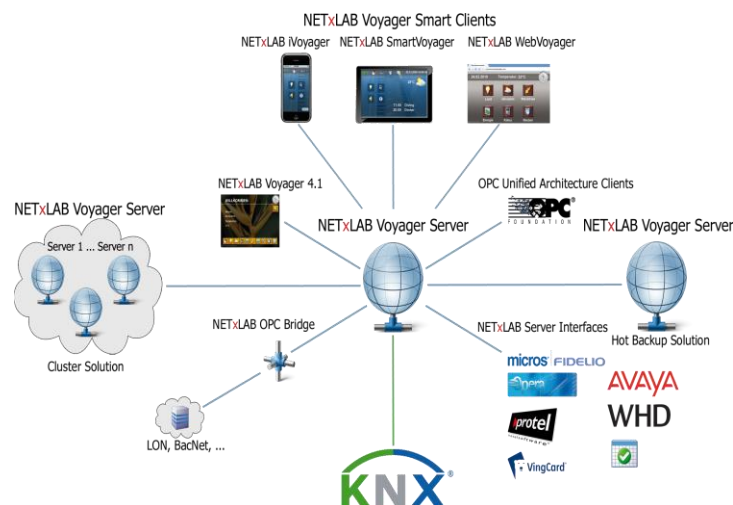


Figure 18: NETX Building Automation Supports OPC UA

The OPC Foundation with the BACnet Users Group has published a specification of how BACnet (ANSI ASHRAE 135 / ISO 16484-5) data can be exchanged using OPC UA. It is expected that this upcoming standard will be supported by the many vendors that currently sell BACnet to OPC DA gateways.

OPC UA Tools and Testing

There are numerous OPC UA SDKs supplied by vendors including:

- Offis UMLbaT: Enterprise Architect Plug-In converts SunSpec UML into OPC UA compatible inputs files.
- Embedded Labs/Matrikon: (C language) Server SDK for ARM microcontrollers and microprocessors
- Unified Automation: (C/C++ and .Net) Client and Server SDKs for Windows, Linux, Unix, iOS, and a number of embedded platforms.
- Prosys: (Java) Client and Server SDKs for Windows, Linux and Android
- Softing: (C/C++ and .Net) Client and Server SDKs for Windows, Linux, and a variety of embedded platforms.
- HB-SoftSolution: (Java) Client and Server SDKs for Linux Embedded, Windows, Linux, Mac OS X
- TerxaSoft: (.Net) Client and Server SDKs for Windows
- Advosol: (.Net) Rapid Server Toolkit
- Oberon Microsystems AG: (JavaScript) OPC UA Client
- OPCLabs: (.Net) Quick OPC-UA Client
- TeslaSCADA: (Java) Client SDK for Android
- Advosol: (.Net) Server SDK for Windows
- Software Toolbox: (.Net) Client and Server SDKs for Windows
- Fraunhofer IOSB: Windows hosted modeling tool.
- CAS: Windows hosted modeling tool
- Technosoft: (.Net) Client and Server SDKs for Windows

Open Source Toolkits/Projects for OPC UA include:

- OpenOPCUA: (C/C++) Client and Server SDKs for Windows, Linux, and a variety of embedded platforms: www.openopcua.org/
- Unified Architecture Framework: <https://github.com/uaf/uaf>
- OpenSCADA (Java) Client SDK: <http://openscada.org/>
- OPCyUA (python): <http://opycua.sourceforge.net>
- Odysseus Open Source Complex Event Processor
- Open OPC UA Server (Java) Server SDK: <http://code.google.com/p/open-opc-ua-server/>
- OPC Foundation (Java, C++, .Net) Client and Server SDK's for OPC Foundation members: www.opcfoundation.org

Protocol Analyzers:

- Wireshark has an OPC UA Plug-in: See <http://wiki.wireshark.org/OPC>

The OPC Foundation provides Compliance Test Tools (CTT) for OPC UA products, which OPC Foundation members can download and execute. For servers, the tests are provided in the form of an OPC UA client application which has been designed to automatically execute a series of verification tests by interoperating with the server under test. The Compliance Test Client generates a test result that the vendor uploads to the OPC Foundation for publication within

the online catalog. To ensure the integrity of the test report it is encoded by the test client as it is created.

The Self Certification tests are designed to fully verify that the interfaces of the server under test respond to client requests in compliance with the specification. Despite the thoroughness of the tests the internal behavior of the server can only be verified to a certain extent. The test cases are designed to verify the behavior of the server using both valid parameters when making calls as well as invalid parameters. It is important to not only verify that a server is compliant under normal conditions but also when a client is not as well behaved as it should be. The results are recorded in a file and can be issued as a summary.

For clients, the OPC Foundation offers Compliance Test Tools (CTT) that are provided in the form of an OPC UA server application. This application has been designed to automatically execute a series of verification tests by interacting with the client under test. The test server cannot track the behavior of the client being tested, thus to confirm compliance, operation of the Client Test must be witnessed by an OPC observer. The OPC Foundation provides observers – the Certification Test Lab personnel – for the remote observation of client behavior.

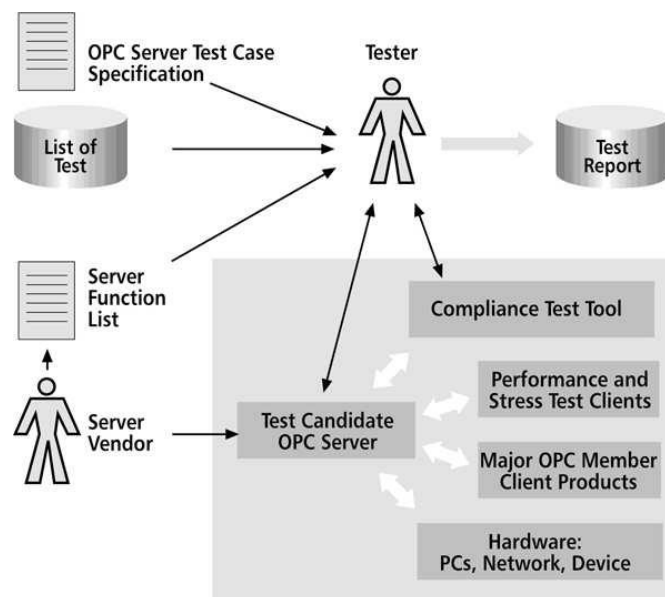


Figure 19: OPC Foundation Compliance Test Tool